# The Mallnitz synform and its relation to the Mölltal fault (Tauern Window, Eastern Alps/Austria)


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## INTRODUCTION

Between Brenner in the West and Katschberg in the East, with a length of more than 160 km, the Tauern Window is the most prominent tectonic window of the Eastern Alps. Within Subpennninc nappes derived from the European continental margin and Penninic nappes derived from the Alpine Tethys ocean are exposed under the Austroalpine nappes (**Fig. 1**). Two of the most prominent structures in the eastern part of the Tauern Window are the Mallnitz synform, affecting the Subpenninic and Penninic nappes, and the Mölltal fault, which is bounding these nappes towards the Austroalpine nappes. Further to the southwest the Mölltal fault continues within the Austroalpine nappes. Both structures are orientated NW-SE and were interpreted to be continuing into each other (Reddy et al, 1993; Kurz & Neubauer, 1996). The joined structure is interpreted as a stretching fault with an offset of about 24 km.

Mapping in the scale 1:10000 in addition to structural and geochronological investigations were performed to get more insight in the structural evolution of the area.

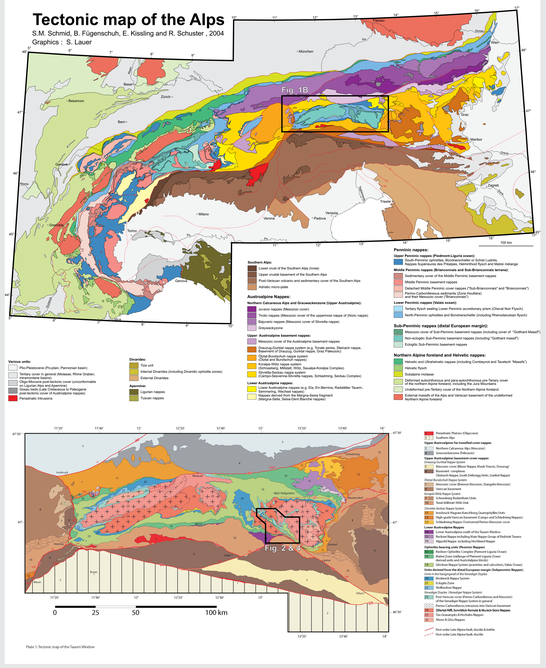


**Fig. 1:** Position of the working area within the Alpine orogene: A) Tectonic map of the Alps according to Schmid et al. (2004). B) Tectonic map of the Tauern Window according to Schmid et al. (in prep.). The polygone indicates the position of the map of Fig. 3 and Fig. 5.

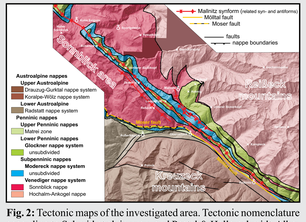


**Fig. 2:** Tectonic maps of the investigated area. Tectonic nomenclature according to Schmid et al. in prep. and Pestal & Hellerschmidt-Alber (2011).

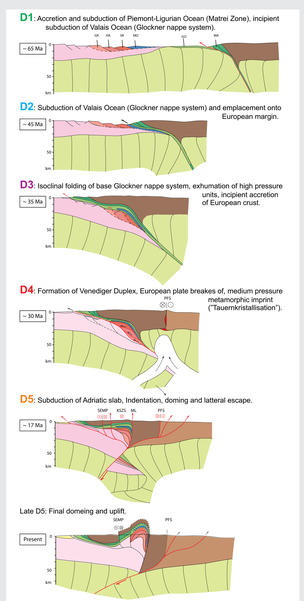


**Fig. 3:** Deformation scheme for the Subpennninc and Penninic units within the Tauern Window according to Favaro et al. (2012).

MA...Matrei Zone; GO... Glockner nappe system; GK, HA, SR... elements of Venediger nappe system; PFS... Periadriatic fault system; SEMP.. Salzach-Ennstal-Mariazell-Puchberg fault; ML... Mölltal fault; KSZS... Katschberg shear zone.

## REGIONAL GEOLOGY

The internal tectonic and lithostratigraphic nomenclature of the Tauern Window is complicated and very heterogeneous (e.g. Kober, 1920; Staub, 1923; Exner, 1971, 1982; Tollmann, 1977). During early investigations a nomenclature with the term "Zentralgneis", "Obere-" und "Untere Schieferhülle" was used, but since Staub (1923) also a subdivision in a Venediger nappe, Modereck nappe, Glockner nappe and Matrei Zone is existing. In the frame of the tectonic subdivision of the Alps by Schmid et al. (2004), and by the knowledge that each of Staub's "nappes" represent several nappes, these terms can be used to establish a relatively simple nomenclature of the Penninic and Subpenninic units in the Tauern Window (**Fig. 2**):

The **Subpenninic nappes** derived from European continental margin (Helvetic shelf) towards the Penninc ocean (Valais and Piemont-Liguria ocean) which existed from Middle Jurassic to Eocene time. It consists of a lower **Venediger nappe system** forming thick nappes of pre-Permian crust with huge masses of granitic gneisses ("Zerntralgneise") and minor Mesozoic cover series. The overlying **Modereck nappes system** includes thin nappes and slices dominated by Mesozoic metasediments. Further it includes tectonic mélange zones composed of basement rocks, Mesozoic metasediments and eclogites ("Eklogitzone", external part of the Seidelwinkel nappe).

The **Penninic nappes** represent remnants of the Penninic ocean and relics of continental fragments within the oceanic realm. The Lower Penninic nappes are composed of Cretaceous ophiolites and overlying deep water sediments (e.g. Bündnerschiefer Group) from the Valais ocean. In the Tauern Window the **Lower Penninic nappes** are summarized as **Glockner nappe system**. Within this nappe system eclogites occur in the Glockner nappe sensu stricto in the Großglockner area, whereas the other nappes are characterized by greenshist facies metamorphic conditions. The **Upper Penninic nappes** have a similar lithological content but they derived from the Piemont-Liguria ocean or from the part of the Penninic ocean which opened in the Jurassic. Main parts of the Upper Penninic nappes in the Tauern Window are the **Matrei zone** and the **Nordrahmen zone**.

The deformation history of the units within the Tauern Window was studies by several authors, e.g. Cliff et al. (1971), Kurz & Neubauer (1996) or Rosenberg & Schneider (2008). According to Favaro et al. (2012) the simplified deformation history within Tauern Window`s units starts with nappe stacking in the Upper Penninic (**D1**) and Lower Penninic unit (**D2**), followed by exhumation of these nappes (**D3**), duplex formation in the Subpenninic units (**D4**) and doming brittle exhumation (**D5**) of the units in the Tauern Window (**Fig. 3**).

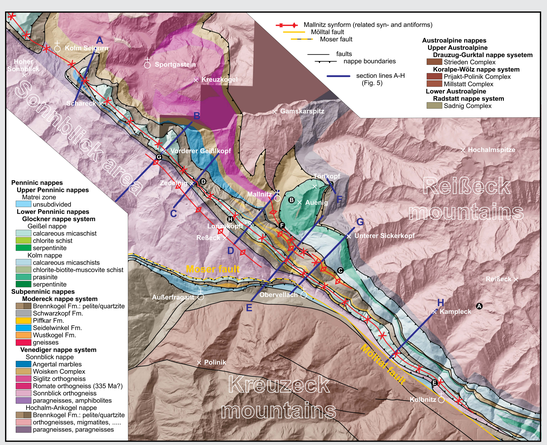


**Fig. 4:** Geological map of the working area (without Quaternary cover). The lithostratigraphy is based on the nomenclature by Frasl & Frank (1966) and Pestal et al. (2009). The lines give the positions of the sections shown in Fig. 5.

## RESULTS

**The Mallnitz synform:** Due to the mapping (**Fig. 2 and 4**), the Mallnitz synform is bordered to the north-east by two basement and cover nappes of the Venediger nappe system, the lower Hochalm-Ankogel and higher Sonnblick nappe. Near to Mallnitz, part of the Sonnblick nappe is folded together with the Kolm nappe, a deep structurally element of the Lower Penninic nappes. Both are overlain by a nappe of the Modereck nappe system and on top by a structurally higher element of the Lower Penninic nappes referred here as Geißel nappe. To the southwest the Mallnitz synform is bounded by the Sonnblick nappe of the Venediger nappe system.

The Mallnitz synform is a predominantly ductile **early D5** structure showing different structural domains along strike (Fig. 4 and 5):

**Section A and B:** In the northwest, between Herzog Ernst and Vorderer Geißelkopf it is an open fold dominated by S2 foliations. In the south-western limb S2 dips to the NE and it is cut by a SW dipping axial plane foliation S5.

**Section C:** Towards the south the Mallnitz synform gets a tight to isoclinal fold. Intensity of S5 increases until become the main foliation. At Zelednig S5 is dipping with c. 30 ° towards SW, at Lonzakopf it is steepened but still SW dipping.

**Section D and F:** Near to Mallnitz in the lower nappes (Kolm and Sonnblick nappe) SW-NE directed structures D4 are overprinted by D5. Form this area towards the SE the sections look more complicated because the Mallnitz synform is dissected by shear zones orientated subparallel to S5.

**Sections G:** Between Mallnitz and Obervellach several synformes and antiformes can be recognized within the main synform structure. S5 is still steeply dipping toward SW.

**Section H:** From Obervellach until Pusaritz, still within the Tauern Window, the synform is rotated and the southwestern limb together with the Sonnblick Lamella (the thin continuation of the Sonnblick nappe towards southwest) is dipping to the northeast. In this area a sinistral shear bands pattern related to the ductile Katschberg shear zone (D5) is present. The steeply dipping, brittle Mölltal fault is not visible in outcrops but it seems that at least two major folds bend around the Danielsberg close to Kolbnitz. The Mölltal fault is a late brittle D5 structure cutting of the earlier S5 foliation of the Mallnitz synform as well as the Sonnblick Lamella.

**The Mölltal fault:** The Mölltal fault is a brittle dextral strike-slip fault with a polyphase history: During a pre-Miocene phase (pre-D5) it was part of a strike slip faults system which caused lateral movements of Austroalpine units with a minor vertical component. This is indicated by different Austroalpine units on both sides of the fault, which cannot fit together by the restoration of the Miocene D5 deformation. During **late D5** deformation the Mölltal fault was responsible for the exhumation of the units within the Tauern Window with respect to the Austroalpine units of the Kreuzeck mountains located in the southwest. The Miocene Mölltal fault is continuing from the Obervellach in the NW until the Periadriatic fault in the vicinity of Villach in the SE. In the NW the Mölltal fault does not propagate into the Tauern Window. Most probably its continuation follows the E-W orientated margin of the Tauern Window (Moser fault sensu Kurz & Neubauer, 1996).

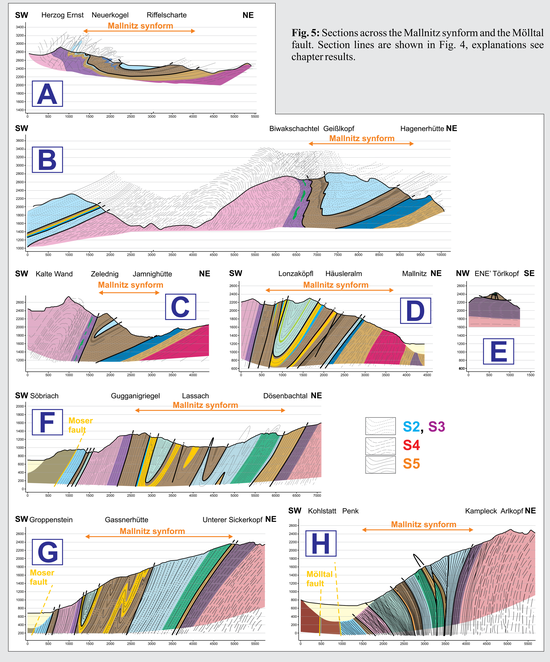


**Fig. 5:** Sections across the Mallnitz synform and the Mölltal fault. Section lines are shown in Fig. 4, explanations see chapter results.

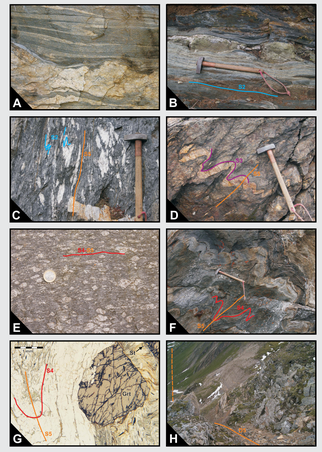


**Fig. 6:** Structures and their relation to the phases of the simplified deformation history. Locations of pictures are given in Fig. 4: **A)** Variscan Deformation in migmatic rocks of the Reißeck Complex located in the Hochalm-Ankogel nappe to the northeast of the Mallnitz synform (Zandlacher Boden). **B)** Amphibolites with epidote-rich boudines elongated in SW-NE direction by D2. **C)** Mica-bearing marble (Bündnerschiefer Group) of the Kolm nappe with relics of S2 and a dominating schistosity S5 (Kaponiggraben, Obervellach). **D)** Micaschists with quartz mobilisate layers of the Brennkogel Formation characterized by a S3 foliation overprinted by S5 (Biwak hut south of Vorderer Geißlkopf). **E)** Granitic Augengneiss of the Sonnblick Lamella deformed by composite foliation S4-S5 (Sonnblick nappe; Riekengraben). The outcrop is located at in the Kolm nappe to the northeast of the Mallnitz synform (Auenig). **F)** Amphibolites, paragneisses and quartzites with NE-dipping S4 foliation crosscut by foliation S5 of the Mallnitz synform ("Altes Dach" of Sonnblick nappe, Biwak hut south of Vorderer Geißlkopf). **G)** Micaschist of the Woisken Complex with garnet and staurolite growing syn to postdeformative to S4. S4 is overprinted by folding F5 and a grenulation cleavage S5 related to the formation of the Mallnitz synform (Sonnblick nappe; Mallnitz). **H)** D5 shear zone with slices of Permian arcosegneisses and Triassic marbles bordering the calcareous micaschists of the Geißl nappe and micaschists of the Brennkogel Formation of the Modereck-nappe system. (Crest between Törlkopf and Reßeck).

## CONCLUSIONS

The Mallnitz synform is a Late Oligocene to Miocene ductile (early) D5 structure, whereas the brittle Mölltal fault is a dextral strike-slip fault with a polyphase history including a Miocene (late D5) phase. Both structures do not continue into each other and are characterized be different deformation pattern.

The Mölltal fault does not propagate into the Tauern Window and cuts of the early D5 structures of the Mallnitz synform. However, both structures are interfering during the exhumation and lateral extrusion of the southeastern Tauern Window during Miocene time.

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